DISPENSING TECHNOLOGY ON THE ROUTE TO AN INDUSTRIAL METALLIZATION PROCESS

Latest developments and results of the research project „GECKO“

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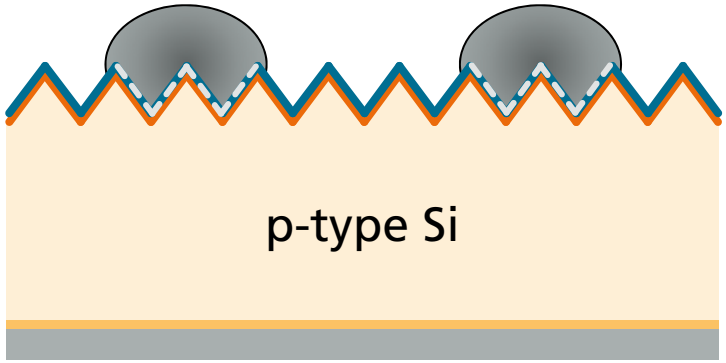
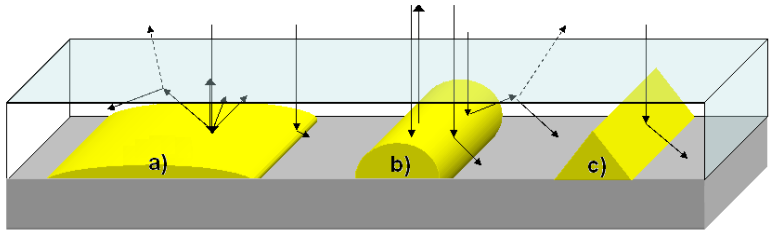
5th Workshop on Metallization

Constance, Tue, 21th October 2014

Front Side Metallization
Process Requirements

- Robust contact formation
- High conductivity
  - → Finger cross-section area A_f
- Less shading losses
  - → Small finger width w_o
- Little (Ag-) paste consumption
  - → Efficient silver usage



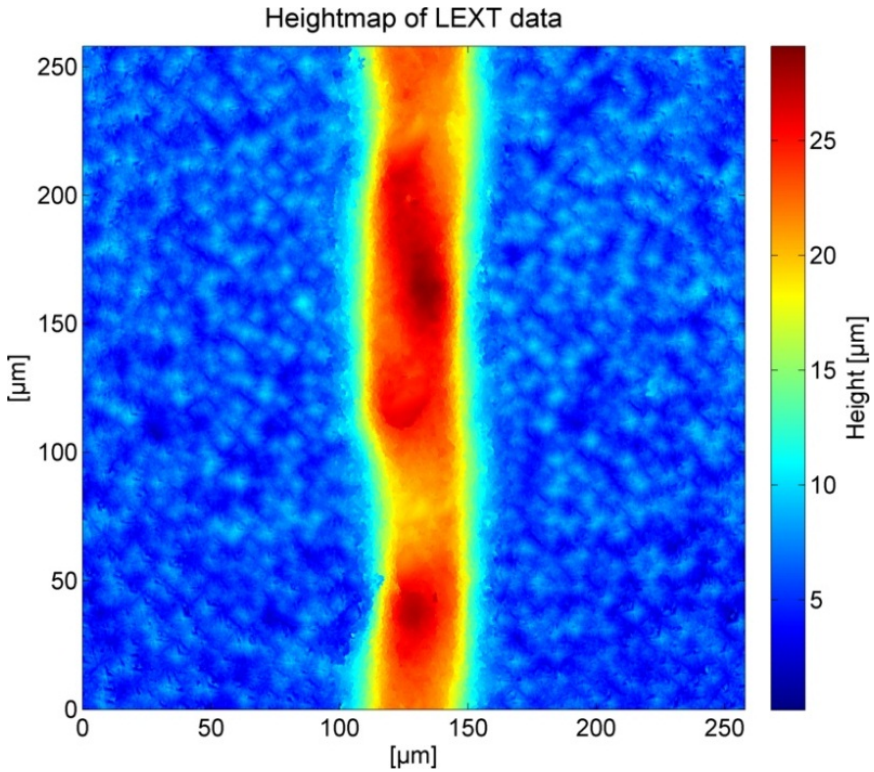


Source: Mette, A., Dissertation Thesis, University of Freiburg, 2007

Screen Printing
… as Industrial Standard Metallization Process

- Established, reliable single step metallization approach
- Robust contact formation
- Throughput rates
  1600 – 1800 Wafer/h

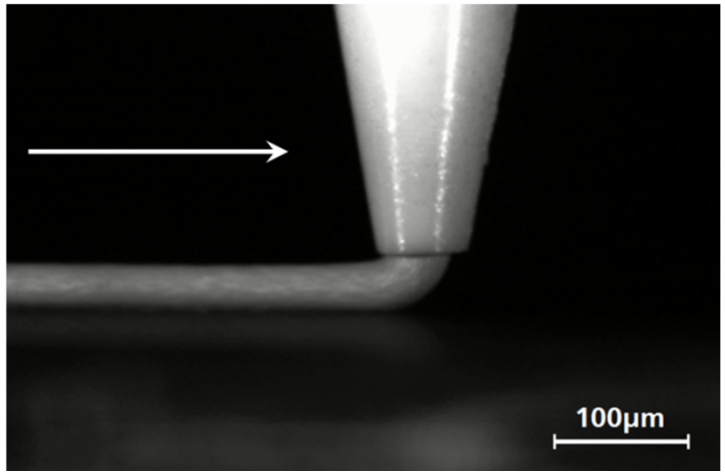
- Finger homogeneity
  (meshmarks and paste spreading)
- Low aspect ratio (= height : width)
- Screen wear
- Mechanical load on wafer

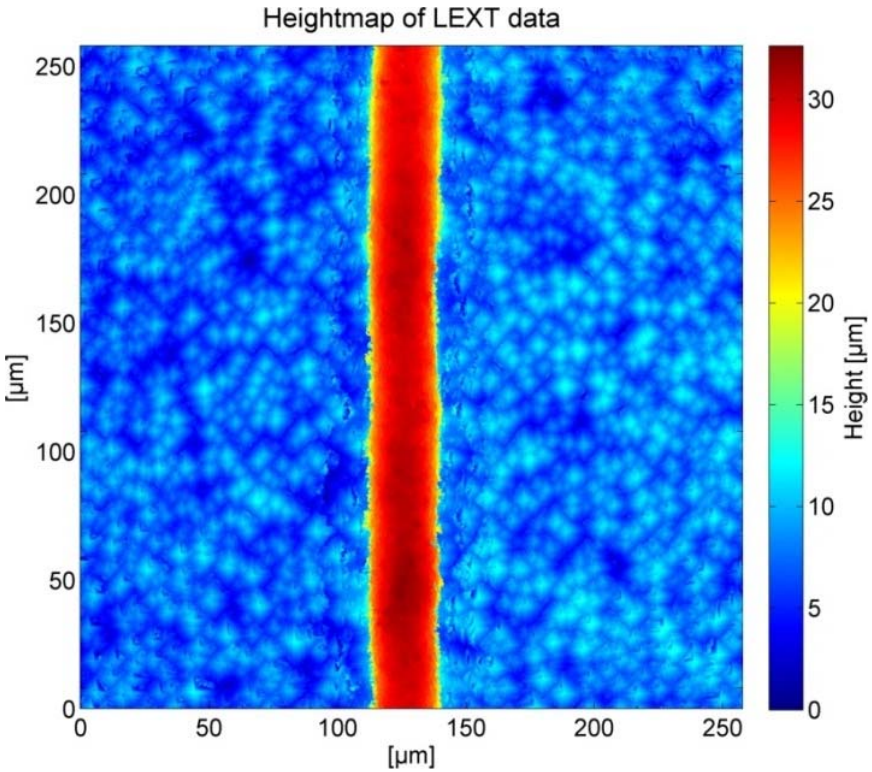


Source: M. Pospischil et al., Energy Procedia 55, 693 (2014)

Dispensing Technology for Front Side Metallization
Opportunities

- Non-impact, single step process
- High resolution, high aspect ratio using **similar Ag-pastes**
- Improvement of cell-efficiencies
  $\Delta\eta = 2 - 3\%_{rel.}$ [1] → $\eta_{max} = 20.6\%$ [2]



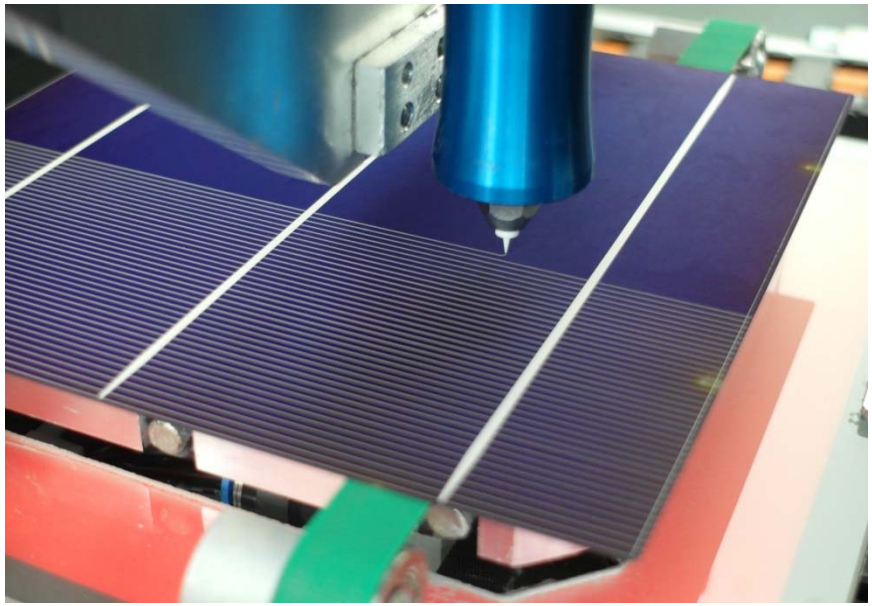


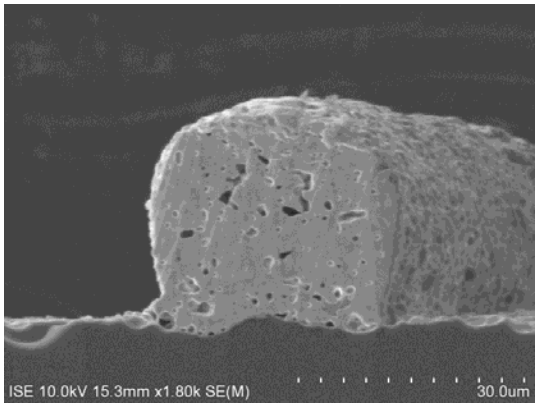
Source: M. Pospischil et al., Energy Procedia 55, 693 (2014)

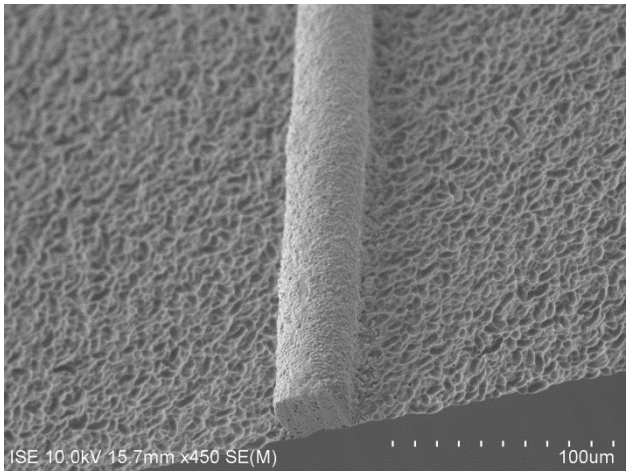
* Sources:
(1) Specht et al., EUPVSEC 2010,
(2) Lohmüller et al., IEEE Electron, 2011

Dispensing Technology for Front Side Metallization
Challenges

- Process stability & accuracy
- Throughput
- Economic Boundaries



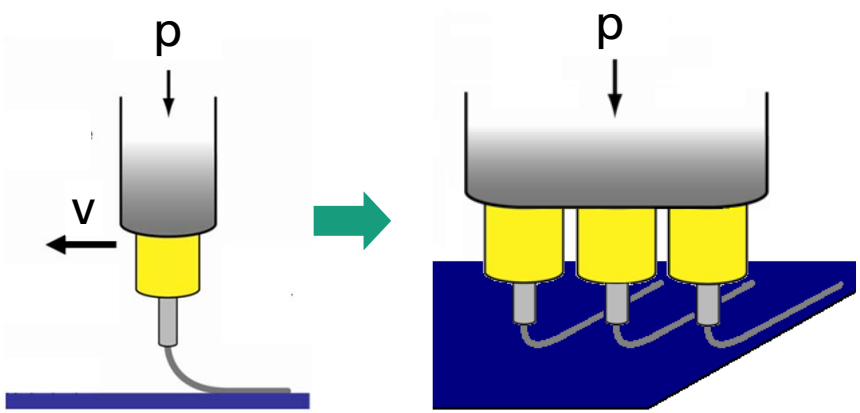


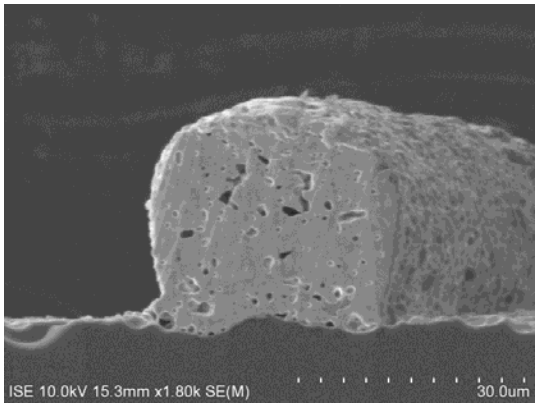


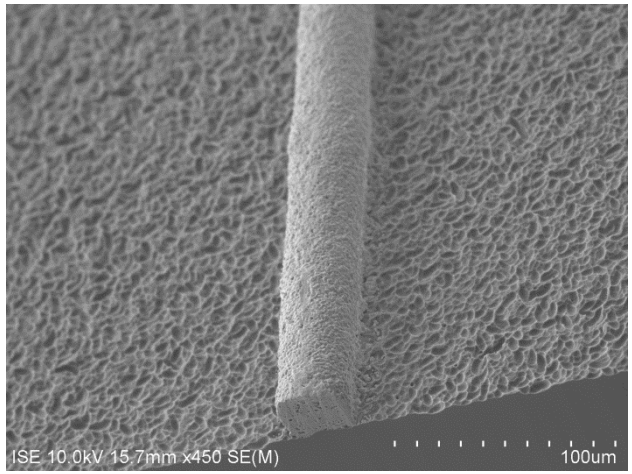
Dispensing Technology for Front Side Metallization
Challenges

- Process stability & accuracy
- Throughput
- Economic Boundaries

→ Parallelization

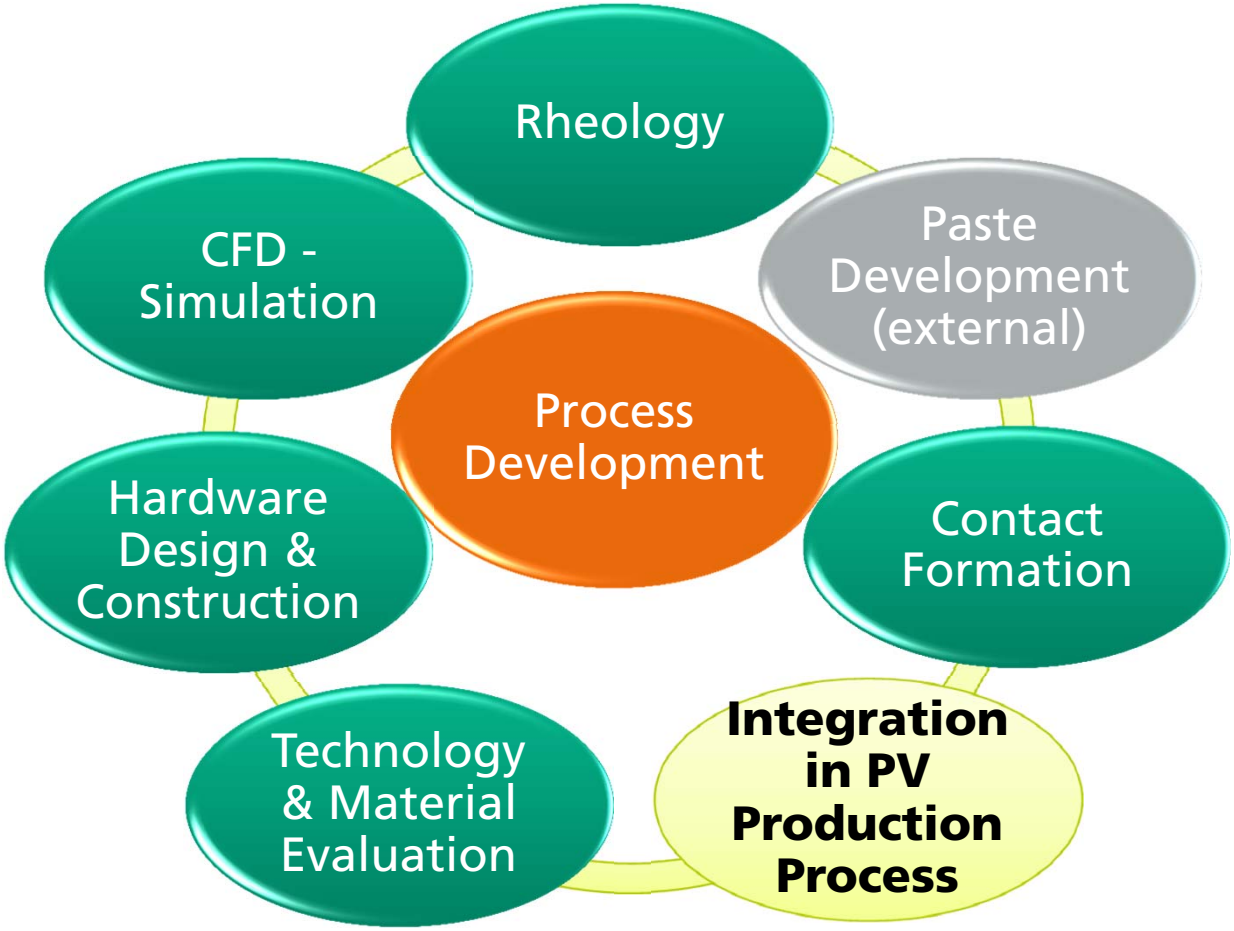






Developing an Industrial Metallisation Process

Interacting Fields of Research and Engineering



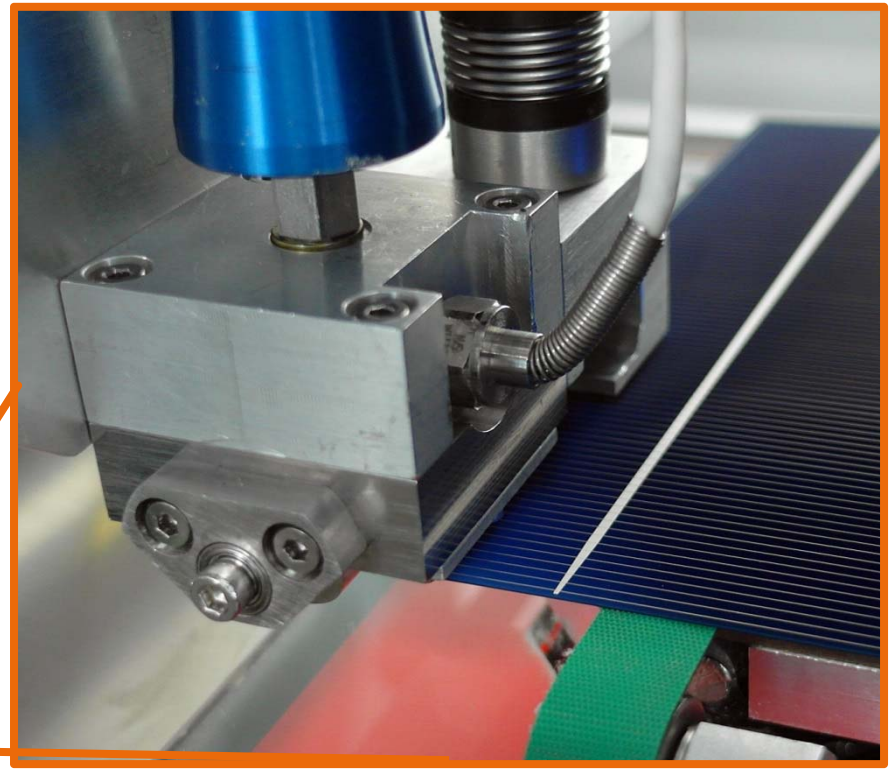
- Integration into new developed dispensing platform
- Development of advanced dispensing pastes
- Cell Processing and Characterization

Multi Nozzle Print Head
Integrated in Industrial Dispensing Platform

- Multi Nozzle Print Head
- Printing speed > 700 mm/s
- Nozzle Plates with ten nozzles
  - → Pitch 1.55mm, N = 100
- Advanced valve technology in development

Platform

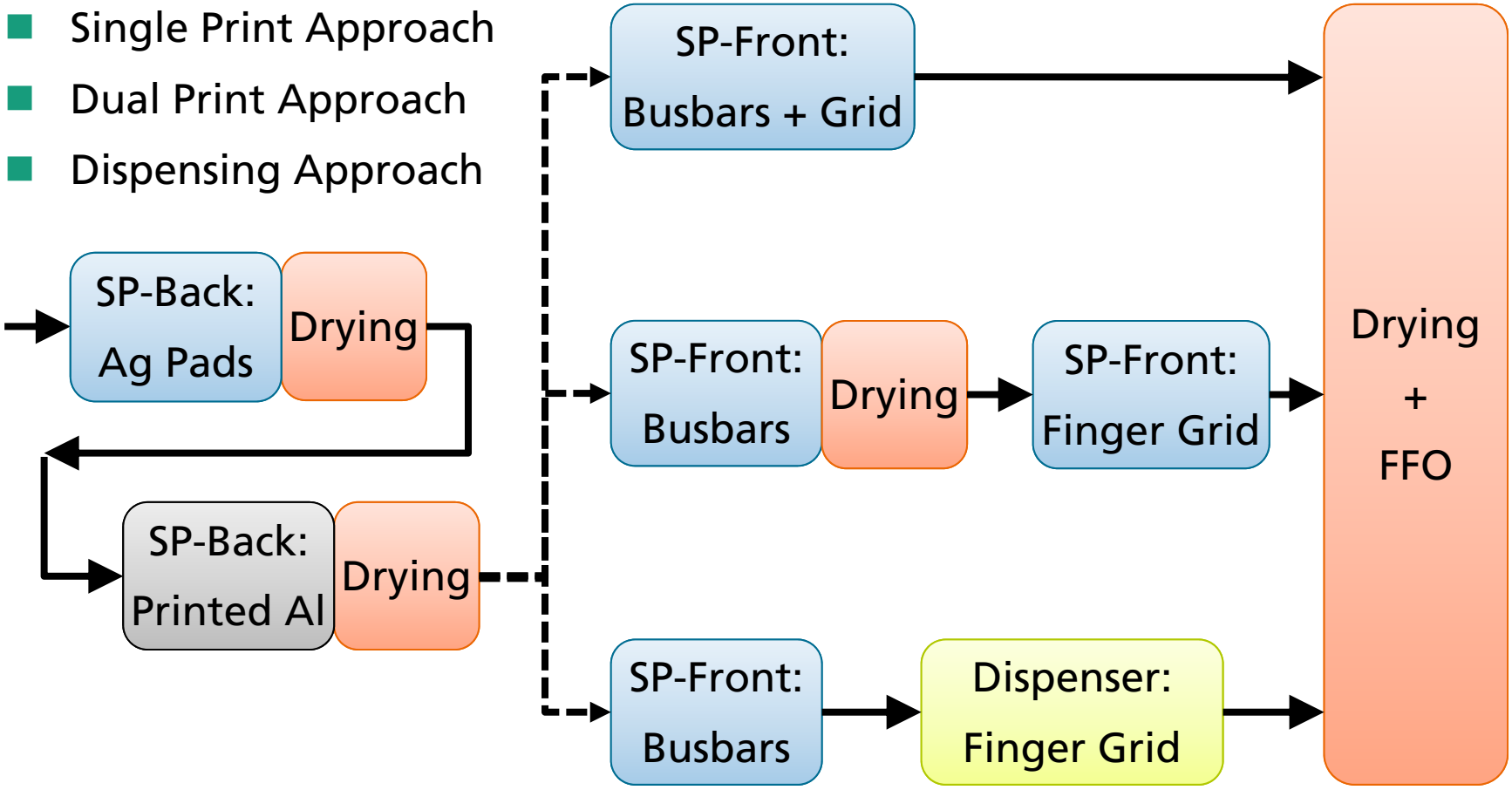
- Inline feasible dispensing platform
- Future scalability



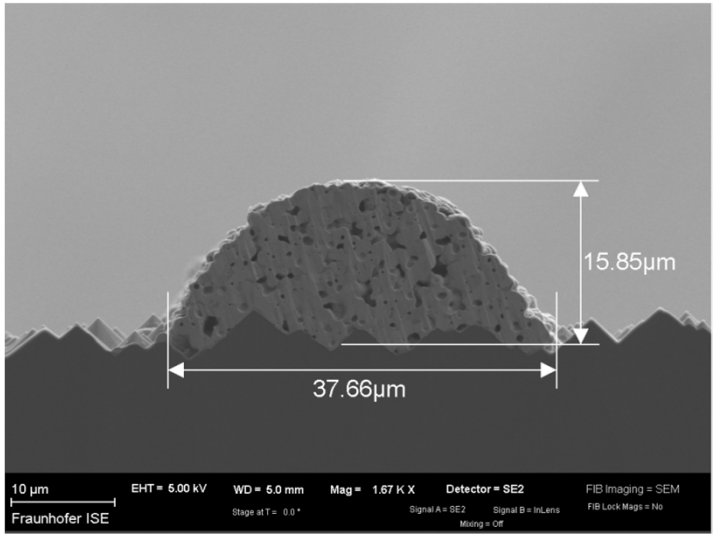
Multi-nozzle print head, mounted in industrial dispensing platform at Fraunhofer ISE's PV-TEC

Design of Production Line
Dispenser as Drop-In-Replacement

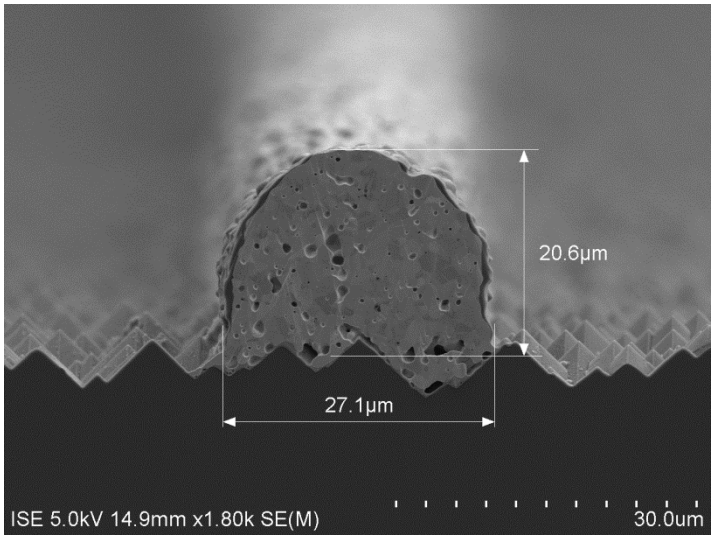
- Single Print Approach
- Dual Print Approach
- Dispensing Approach



Resulting Finger Geometries of Dispensed Contacts
Influence of Paste Rheology



SEM sample of dispensed contact finger with paste designed for screen printing



SEM sample of dispensed contact finger with adapted paste rheology*

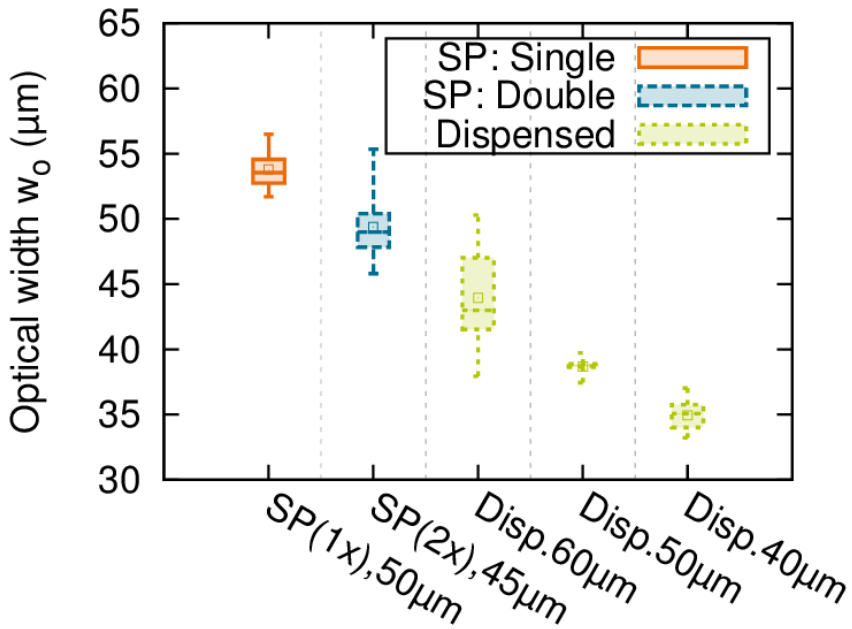
- Pastes designed for screen printing gives increased homogeneity at medium aspect ratios (AR).
- Rheological adaptation allows for further increased AR at similar finger cross section areas.

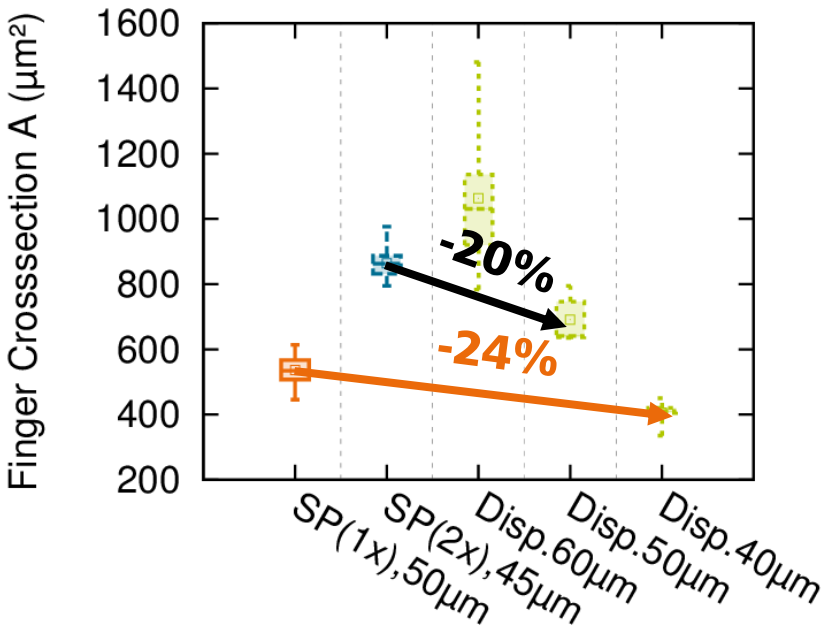
→ **Evaluation of pastes possible prior to rheological adaption!**

*M. Pospischil *et al.*, Energy Procedia **43**, 111 (2013).

Resulting Finger Geometries of Printed Contacts

Finger Widths and Cross Section

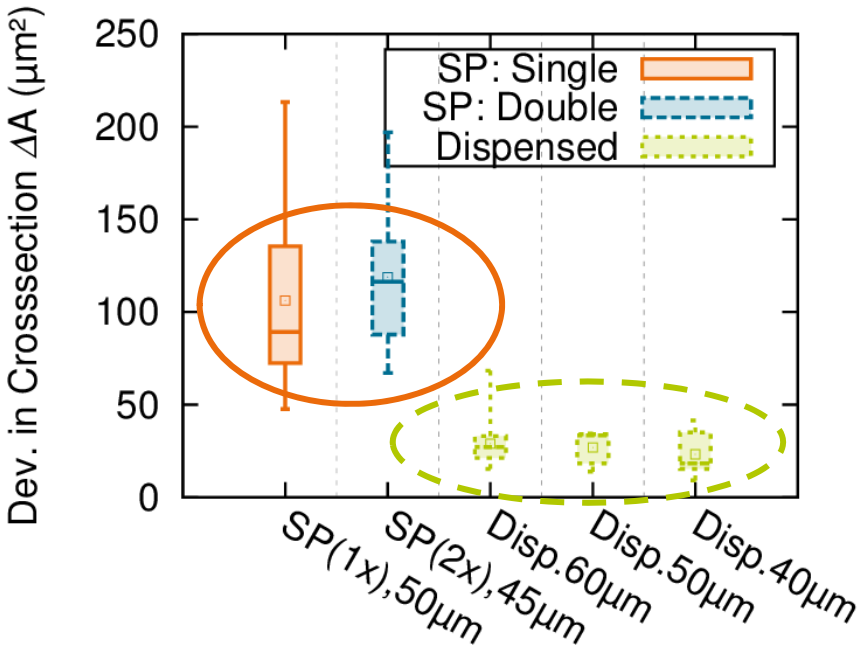


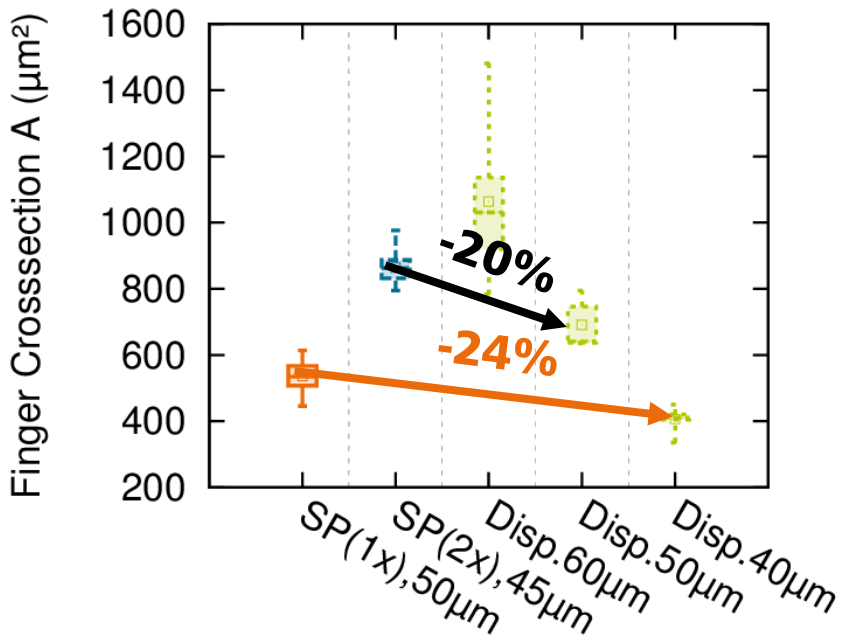


- Stable processing of homogeneous dispensed contact grid with finger widths < 40µm
- Cross section area A_f in the range of screen printed references at Nozzle openings of D < 60µm

Resulting Finger Geometries of Printed Contacts

Improved Finger Homogeneity

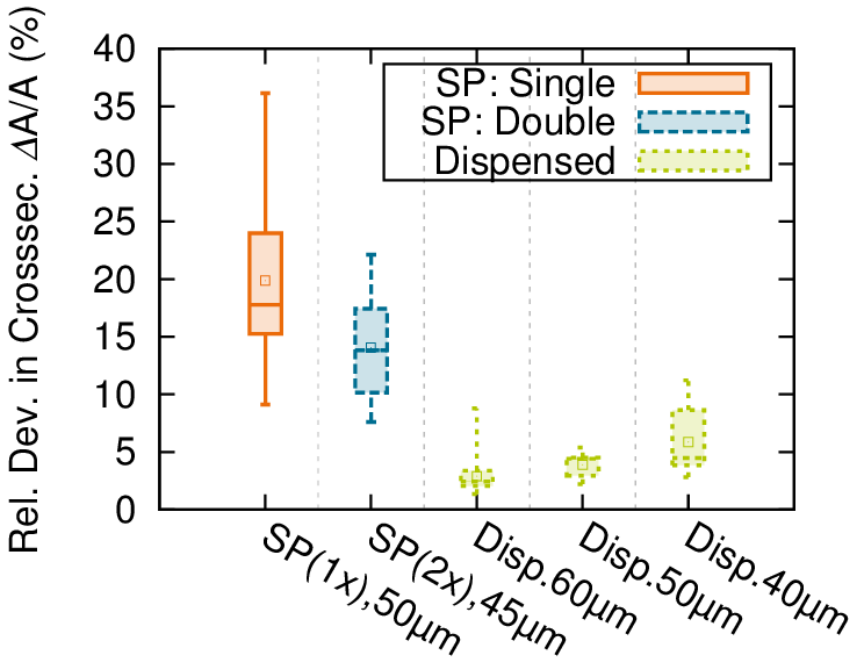


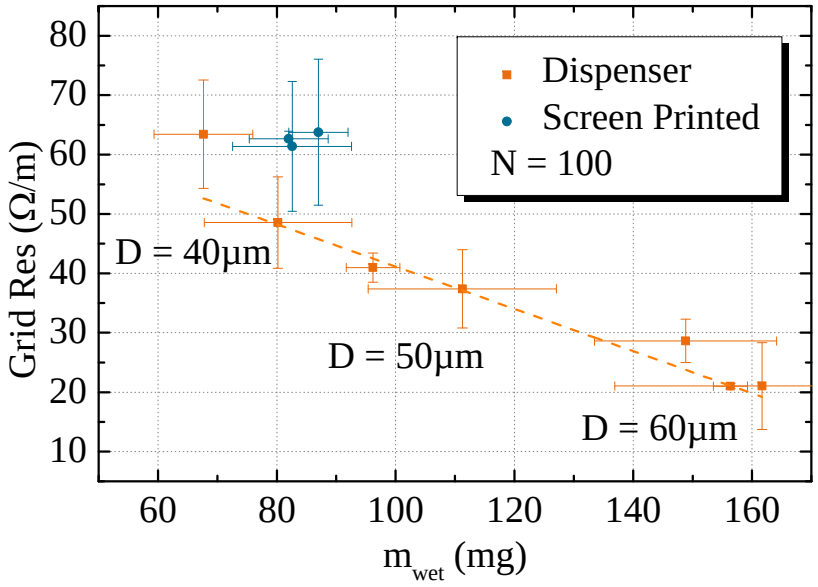


- Visualization of mesh marks (SP)
- Improved finger homogeneity for all dispensed samples
- Cross section area A_f in the range of screen printed references at Nozzle openings of D < 60µm

Resulting Finger Geometries of Printed Contacts

Improved Effective Silver utilization



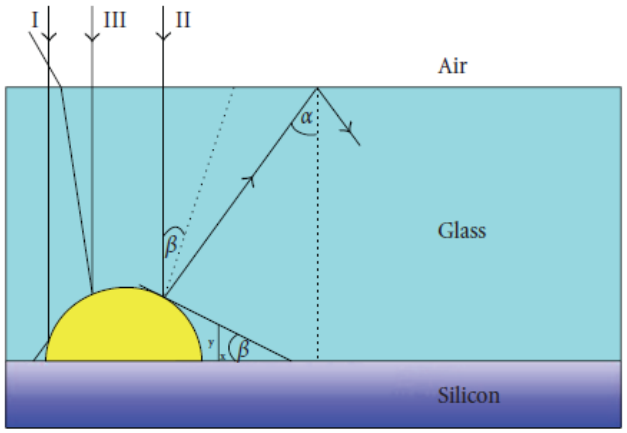


- Relatively higher impact of inhomogeneities with decreasing finger width
- Significantly improved finger homogeneity increases effective silver utilization by 20%

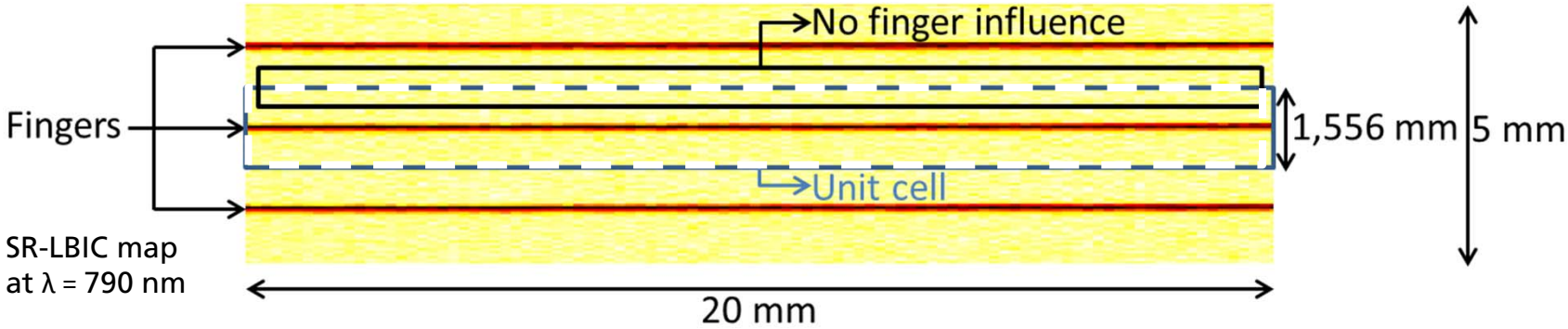
Characterization of Finger Geometries
Effective Widths by SR-LBIC

- SR-LBIC maps of EQE (Beutel et al.*)
- Extraction of finger contribution to j_{sc} possible without special sample preparation

  → Effective finger width (EW)**



*Source: Woehl et al.***



*M. Beutel *et al.*, Solar Energy Materials and Solar Cells (2014).

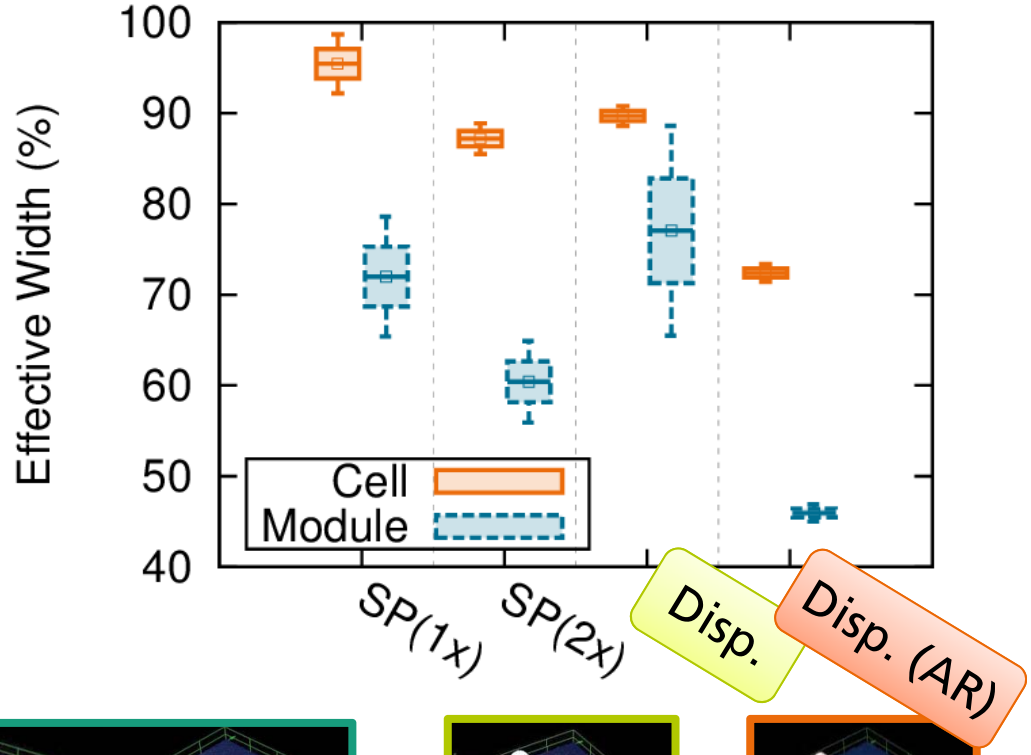
**R. Woehl *et al.* Advances in OptoElectronics (2008)

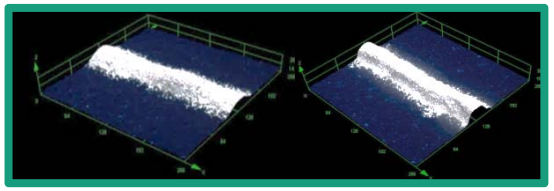
Determination of Effective Finger Withs
Relative Values

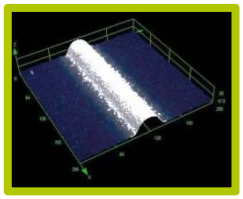
- Relative comparison with geom. width
- High aspect ratio dispensing technology:
- EW_{rel}~73% on cell level!
- EW_{rel} ~ 48% on module level!

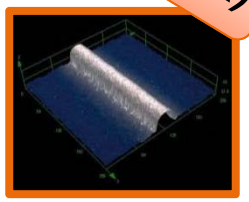
→ EW_{SP}: 72% x 45µm = **32.4µm**

→ EW_{DSP}: 48% x 35µm = **16.8µm**





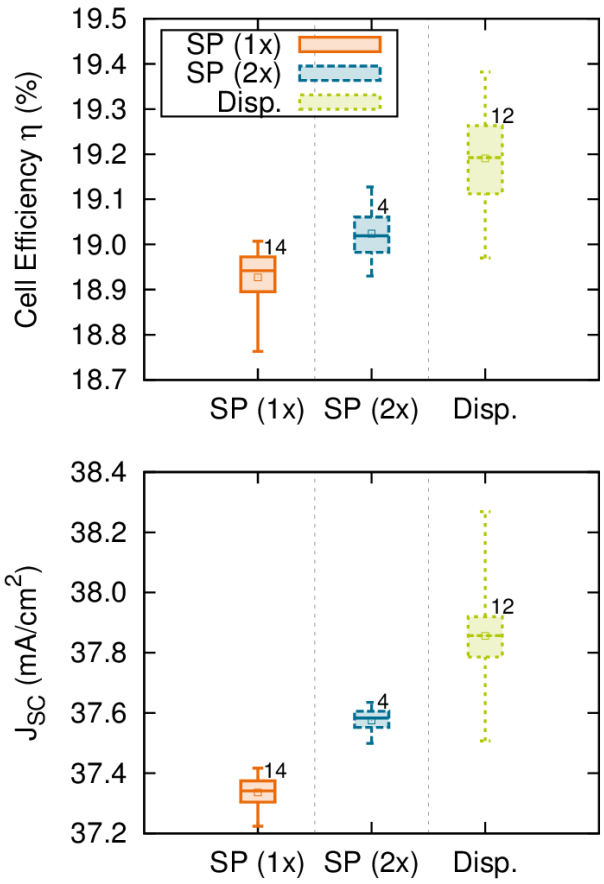




Conversion Efficiencies on Standard Al-BSF
Cell Batch on Industrial Precursor Material

- Cz p-type Si, Emitter: $R_{sh} \approx 90\Omega/sq.$
- V_{oc}: +3mV due to floating Busbar
- J_{sc}: +0.5mA compared to single SP
- $\Delta\eta$: **+0.4%abs**. of best cell compared to single SP
- With dual/double SP (2x): $\Delta\eta$: + **0.3%abs**.

→ **Expected advantages due to advanced finger geometry demonstrated**

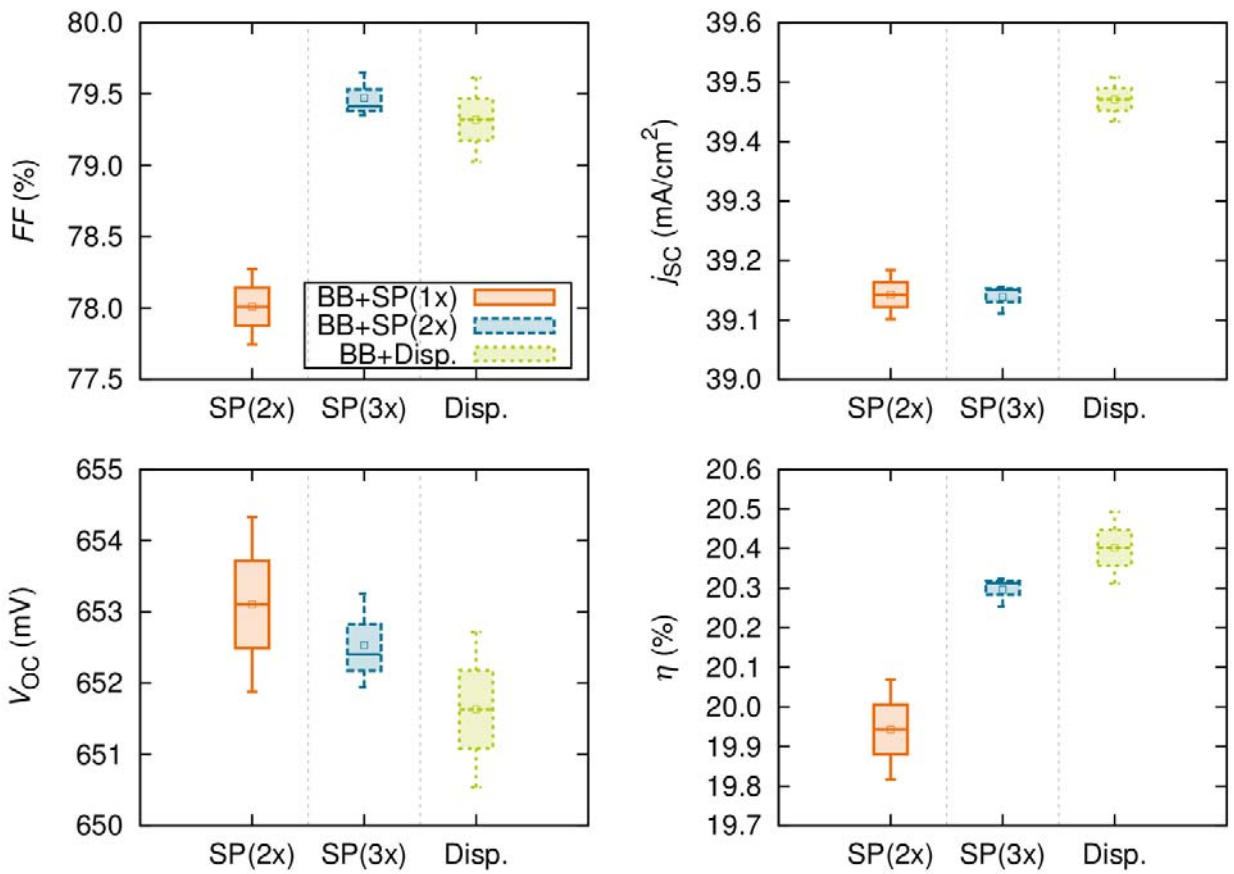


Recent Cell Results on PERC Samples

Cell Batch on Industrial Precursor Material

- Cz p-type Si
- All groups with floating BB
- FF on high level
- J_{sc}: +0.35mA/cm²
- Δη: **+0.4%abs**. of best cell compared to dual SP (2x)
- With dual + double SP (3x): Δη: + **0.2%abs**.

→ **Max. η = 20.5% with Dispensing**



Summary and Outlook
… on the Route to an Industrial Metallization Process

- Advanced Parallel Dispensing Print Head developed and integrated into inline feasible Dispensing Platform at Fraunhofer ISE's PV-TEC

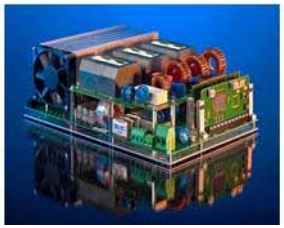
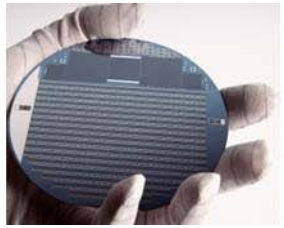
- Substantially improved dispensing pastes allow for
  - Stable processing of < 40µm fingers at ~95mg paste consumption
  - Similar contacting behaviour as screen printing pastes

→ **linked development with fast emerging screen printing pastes**

- High aspect ratio and lower effective width allow for substantially increased cell efficiencies compared to screen printing
  - 19.4% vs. 19.0% on industrial Al-BSF
  - **20.5%** vs. 20.1% on industrial PERC

Thank you for your attention!




… and all Co-authors and Co-workers within the Dispensing Project

… as well as our industry partners:

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